§24. Fast Change in Core Transport after L-H Transition

Kadomtsev, B.B. (Kurchatov Inst.)
Itoh, K.
Itoh, S.-I. (Kyushu Univ.)

The H-mode in tokamak plasmas has revealed many complex features of the plasma transport phenomena. In addition to the fast phenomena near the edge, the transport in the core plasma was also found to respond very rapidly at the L-H transition [1]. The confinement in the core plasma is known to become better in the H-mode plasma. The recent experiment on JET has shown that the improvement in the core starts to occur only a few milli-seconds or less after the L-H transition at the edge. This delay time is much smaller than the time scale of the diffusive transport a^2/χ (a: the distance of propagation such as the minor radius, χ: the thermal diffusivity). This phenomenon of the rapid change in core would be related to other experimental observations, and suggest that the energy flux in the plasma is governed by some 'nonlocal' mechanism, in addition to the diffusive flux driven by the local gradient. A distant interaction of fluctuations was analyzed in a form of the diffusion equation for fluctuations [2], but may not be enough.

A possible physical picture of the rapid change of the transport in the core plasma is discussed. A successive mode change (from L- to H-state) propagates from the edge to the center in a form of avalanche, causing a rapid change in a core.

In L and H modes of confinement, the dependencies $q = -\chi\nabla T$ are very different each other. But we consider them as two different branches of the same nonlinear $q = q[\nabla T]$ dependence, keeping in mind the possibility for the existence of some control parameter C. In the edge plasma, the parameter C was the radial electric field E_r or its gradient [3]. Here the shear flow, i.e., n=0/m=0 mode is responsible for the turbulence suppression (m and n are the poloidal and toroidal mode numbers). Similar type of the gradient-flux relation for the core plasma could be again nonlinear one, either the N-figure type or the S-figure type, and the following argument applies to both cases. These multiple states can be considered again as produced by the effect of the hidden variable or the control parameter. In the core plasma, the candidate for the control parameter is extended to the general axisymmetric potential variation.

The successive L to H transition can propagate quite rapidly. Consider for instance the case when the layer 1 in the core is just jumped to the H-state and the adjunct layer 2 still remains in the L-state. Small change δT is induced in layer 2 by the L-H transition in the layer 1. If this change is enough to cause the transition in the layer 2, the ratio between the heat flux q and $N\delta T$ provides the propagation velocity V (N being the density). Writing the heat flux q as $-N\chi\nabla T$, the velocity V can be estimated as [4]

$$V = \frac{T}{\delta T}\frac{\chi}{a}$$

where we use the simplification $-\nabla T \simeq T/a$. The V value can be much larger than χ/a. Thus, this high propagation velocity allows a rapid transmission of the information. The characteristic time

$$\tau = a/V$$

is estimated as

$$\tau = \frac{\delta T}{T}\frac{a^2}{\chi}$$

This is much smaller than a^2/χ if $\delta T/T \ll 1$ holds.

This picture of the continuous transitions has a similarity to the 'sand-pile model' [10]. If the profile at some location of the mountain of the sand reaches the critical profile of the avalanche, then the avalanche happens. Owing to the local perturbations associated with the avalanche, the barrier of the static frictional force is overcome, and the dynamic friction becomes smaller. The avalanche continues to start in the neighborhood. Due to the successive triggering of the avalanche, the event at the top propagates very fast to the bottom. The self-organized criticality in this problem leads to the formation of the self-similar form of the sand pile.

References

1) S. V. Neudatchin, J. G. Cordey, D. G. Muir: *Proc. 20th European Conference on Controlled Fusion and Plasma Physics* (EPS Conference, Lisboa, 1993) Part I, p.83.
2) A. Yoshizawa: Phys. Fluids **28** (1985) 3313.
3) S.-I. Itoh and K. Itoh: Phys. Rev. Lett. **60** (1988) 2276.
4) B. B. Kadomtsev, K. Itoh, S.-I. Itoh, *Comments Plasma Phys. Contr. Fusion* **17** (1995) in press.